

CHALLENGES IN SOLAR-SYSTEM IONOSPHERES

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Ionospheric Domains

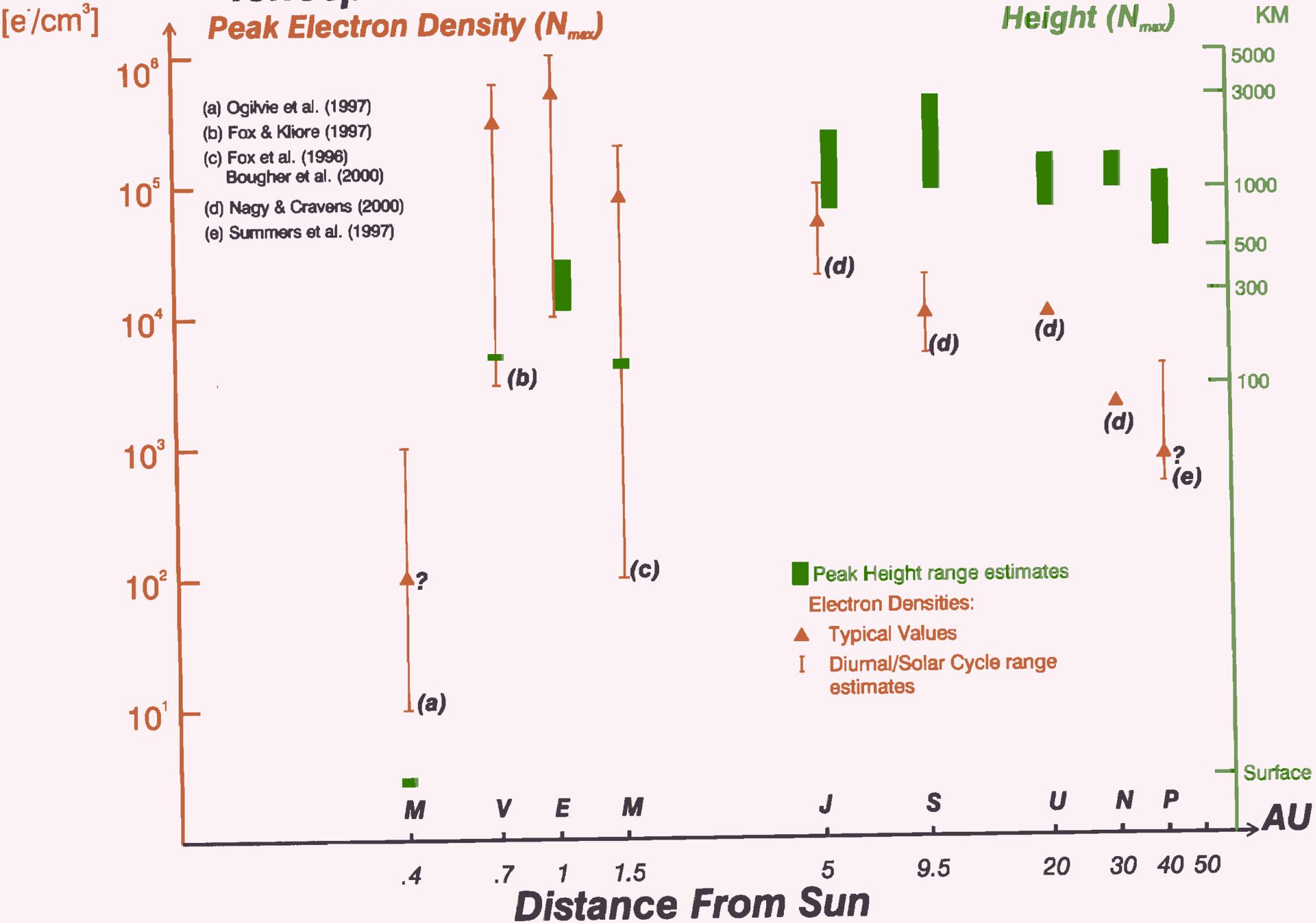
- **Terrestrial Planets:**
 - **Mercury:** Surface-Boundary Exosphere/Ionosphere
 - **Venus, Earth & Mars:** Observed & Modeled
- **Jovian Planets:**
 - **Jupiter:** Best observed; some models
 - **Saturn, Uranus and Neptune:** Few observations; early models
 - **Pluto:** No observations, several models!
- **Satellites of Jovian Planets:**
 - **In “Dense” Atmosphere:**

Io,	Titan	and	Tritan
(Jupiter)	(Saturn)		(Saturn)
 - **In “Surface-Boundary-Exospheres”:** Europa, Ganymede, & Callisto (and probably for large asteroids)
- **Comets:**
 - **Peri-helion:** plasma coma & tail; many cases modeled
 - **Halley:** in-situ observations
- **Extra-solar system Planets:** **No observations; models surely coming!**

CHALLENGE #1: BASIC STRUCTURE

- **Venus, Earth and Mars**
- **Jupiter – in progress with Galileo radio occultations experiment**
- **Saturn – Cassini enroute with radio occultation experiment**
- **Pluto – Mission approved**

Ionospheric Characteristics In The Solar System

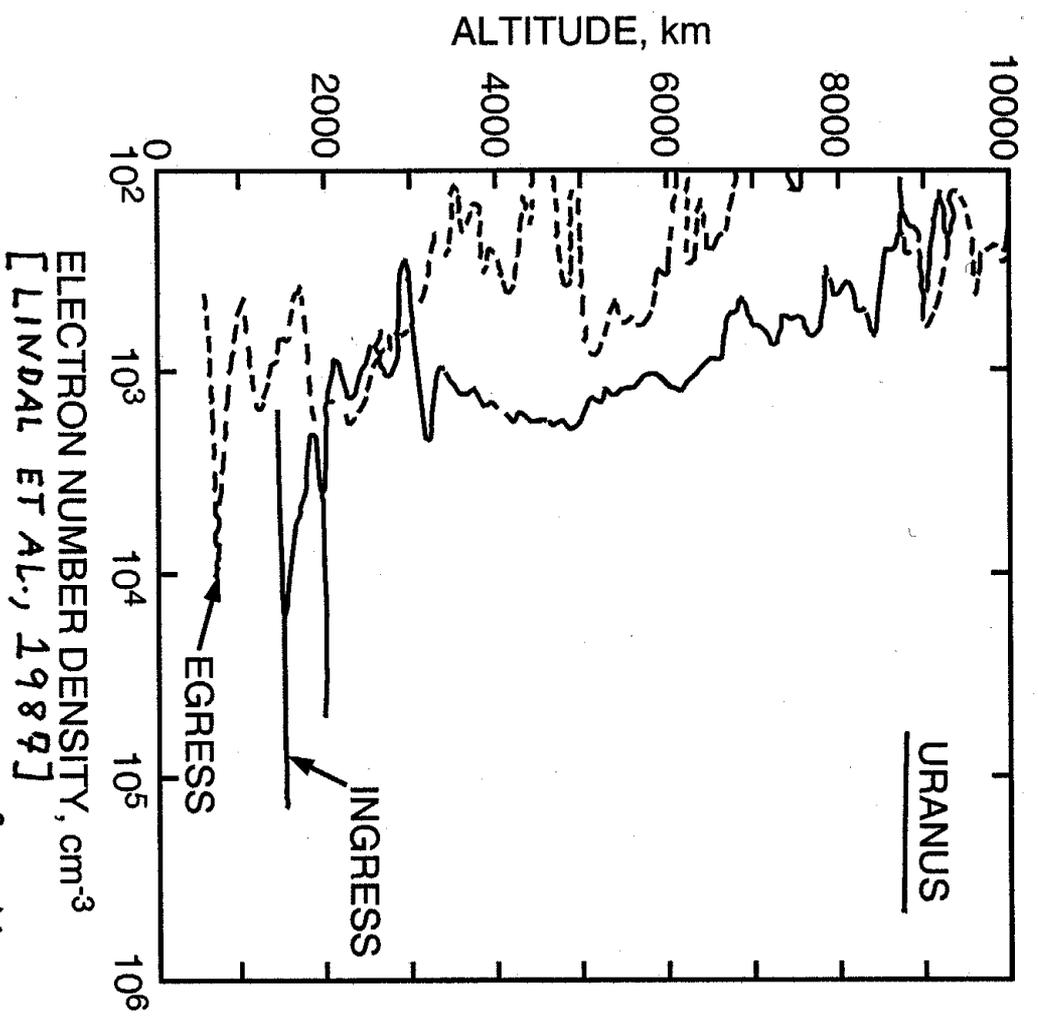
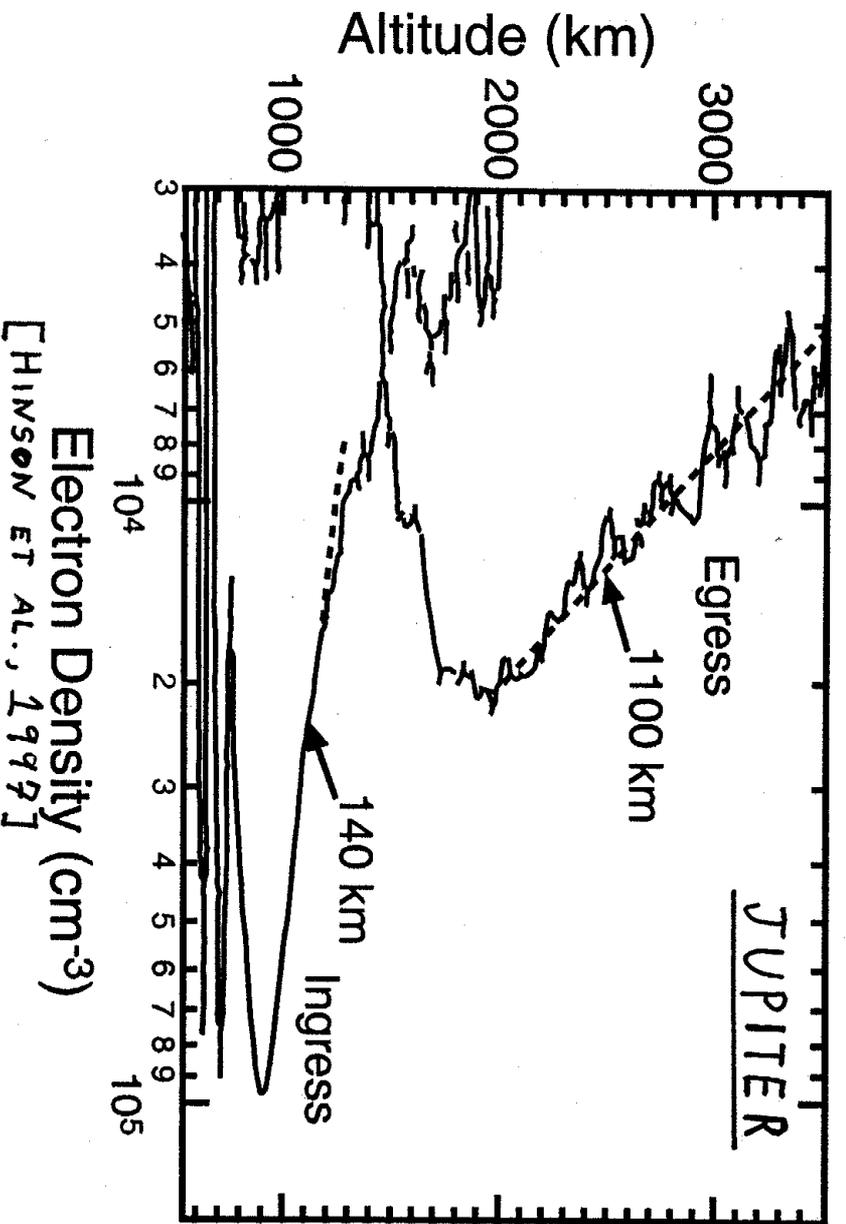


CHALLENGE #1: BASIC STRUCTURE

Example: Jupiter's multiple layers

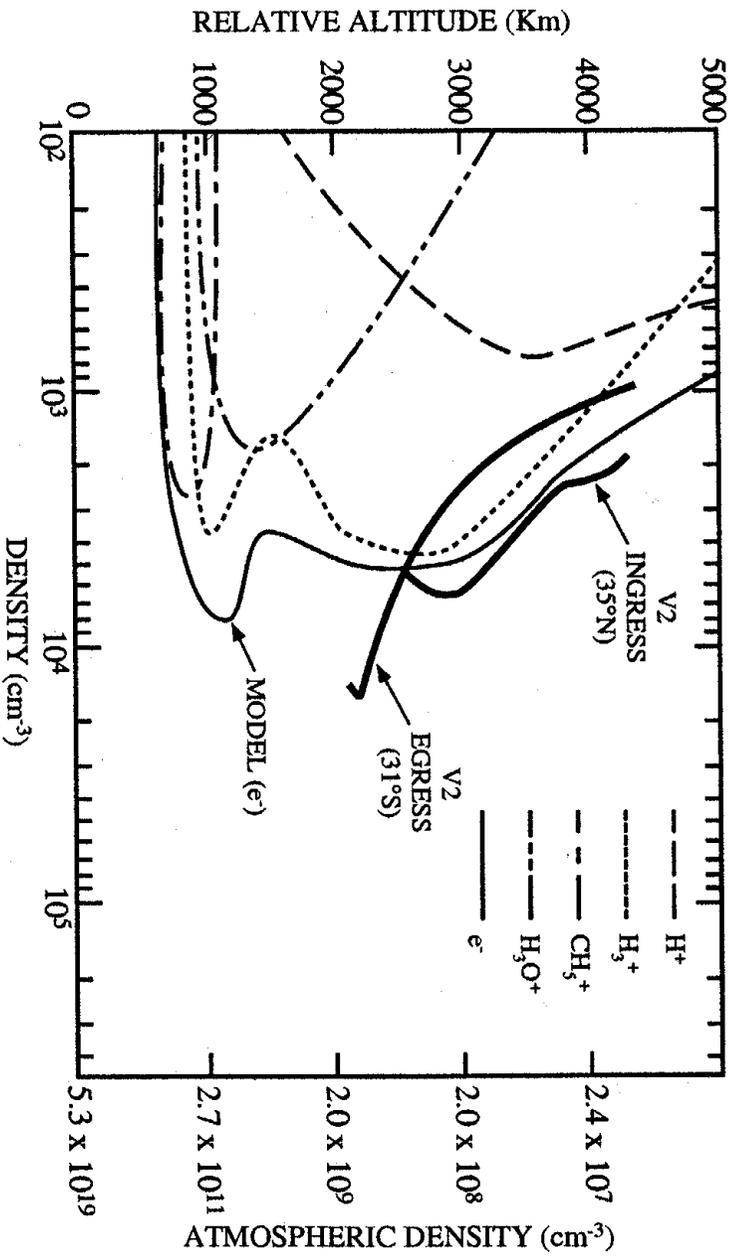
Example: Saturn's model

**Example: Ganymede's occurrence
pattern**

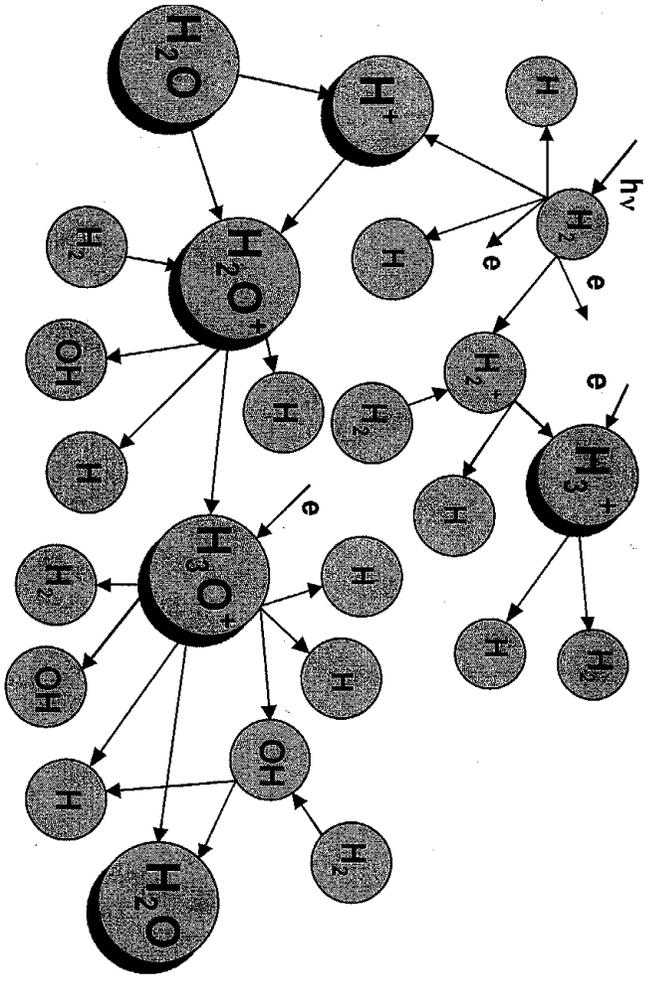


— from Nagy + Cravens (2002)

SATURN IONOSPHERE



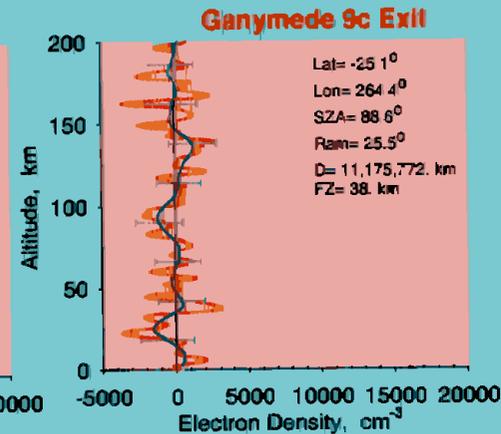
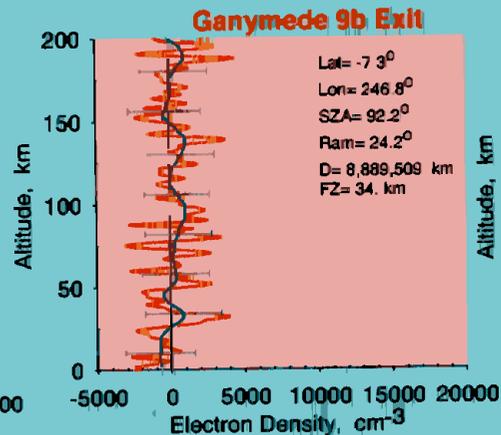
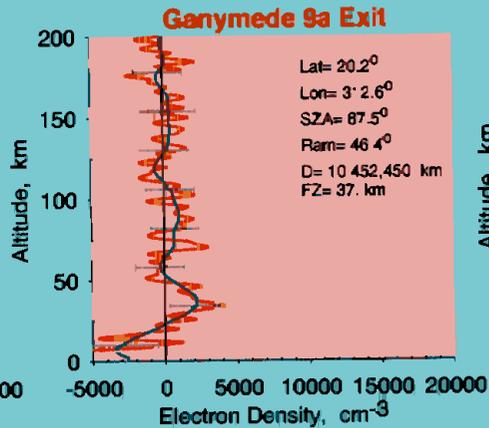
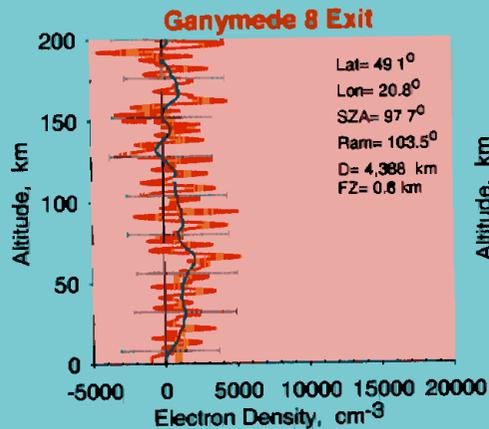
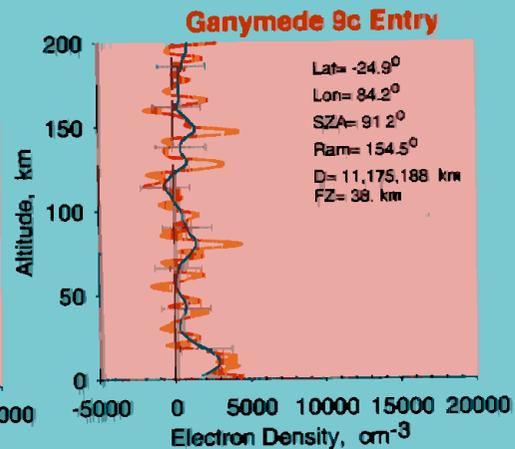
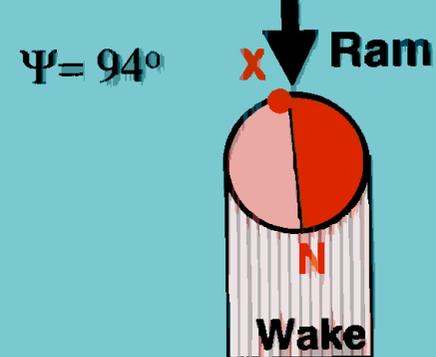
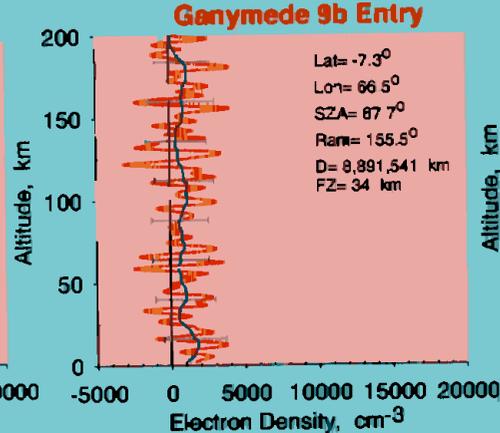
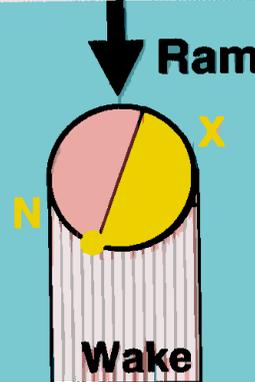
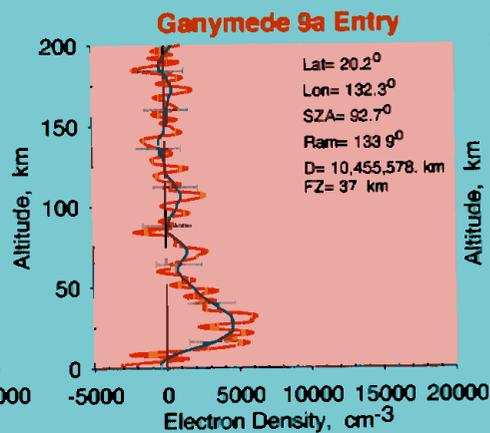
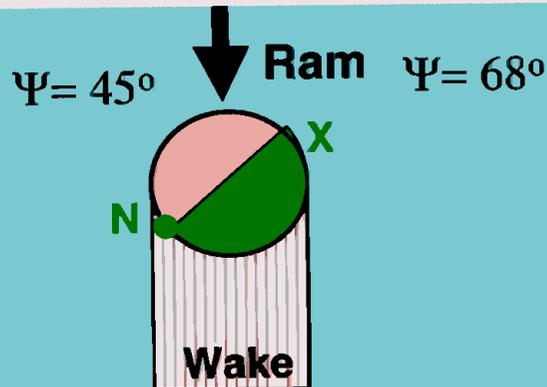
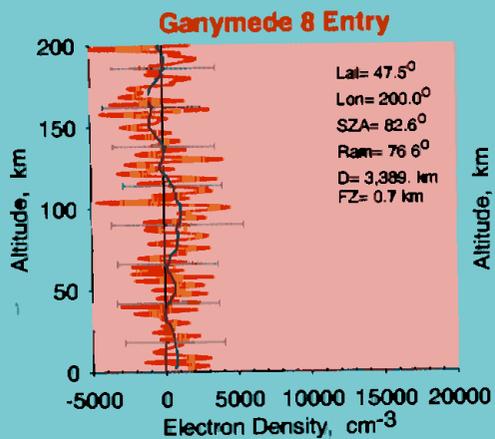
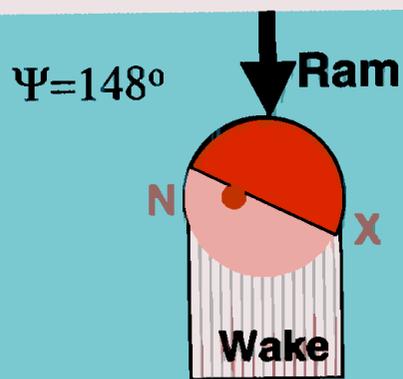
[WAITE + CRAVENS, 1987]



[SCHUNK + NAGY, 2000]

— from Nagy + Cravens (2002)

Kliore et al: GANYMEDE



Conclusions

**Galileo
Radio
Science**

STANFORD



- Ionospheric plasma is only observed during radio occultations of Ganymede and Callisto only under certain geometries - namely when the trailing hemisphere is illuminated by the Sun
- This can be explained as follows:
 1. The neutral atmosphere is created on the trailing hemisphere by sputtering of surface ices by Jupiter's magnetospheric particles.
 2. In order to create an ionospheric plasma that can be observed with radio occultation, these atmospheric molecules (most likely O_2) must be exposed to solar EUV, which happens only if the trailing hemisphere is also in sunlight.
 3. This scenario also explains why very few of the Ganymede occultations produced positive results, compared to Callisto.

CHALLENGE #2: VARIABILITY

Example: Separation of Terrestrial components

$$\sigma^2 (\%) = \sigma^2_{\text{TOTAL}} = \sigma^2_{\text{SOLAR}} + \sigma^2_{\text{MAGNETIC ACTIVITY}} + \sigma^2_{\text{METEOROLOGICAL}}$$

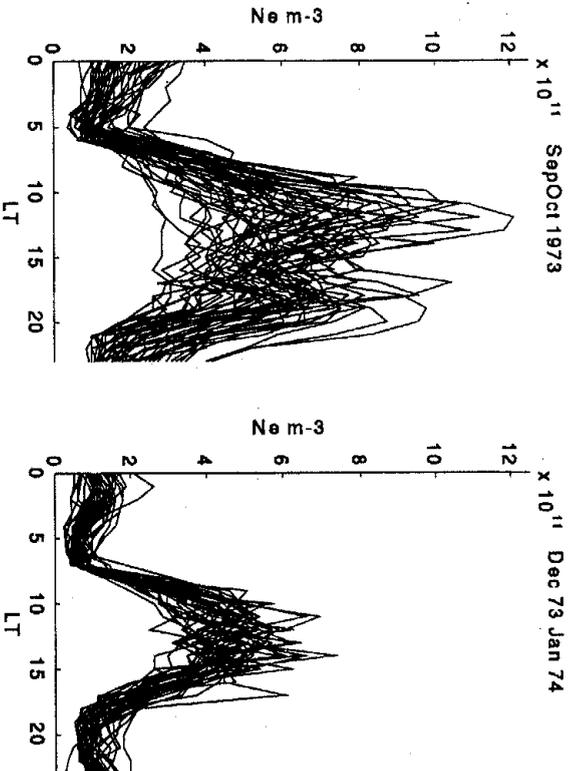
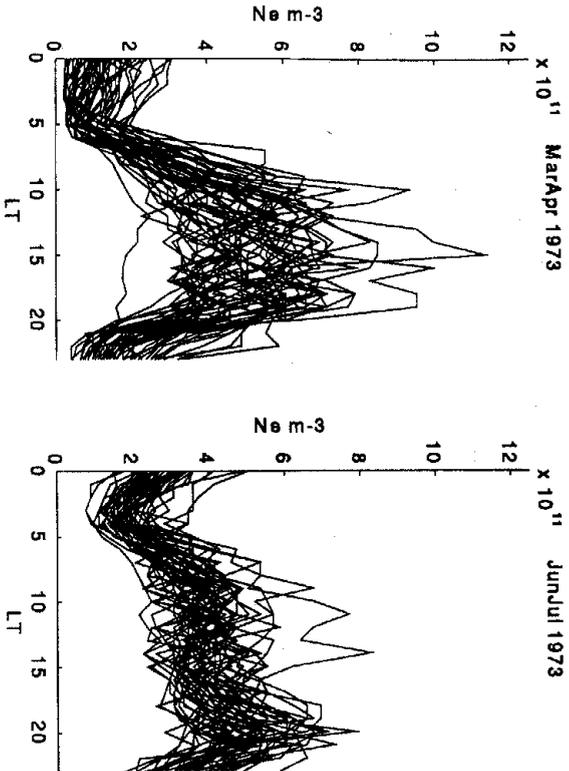
Example: Modeling Coupling from below at Earth

Example: Space Weather at Mars



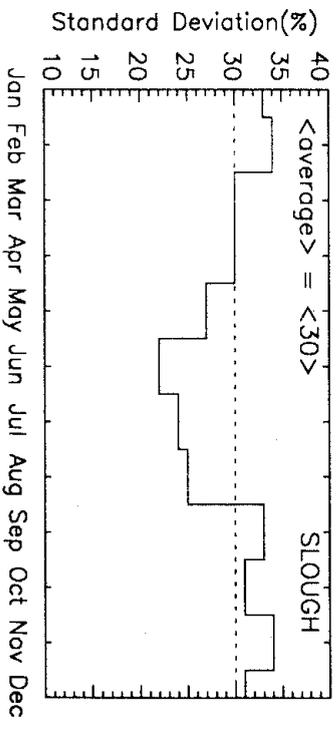
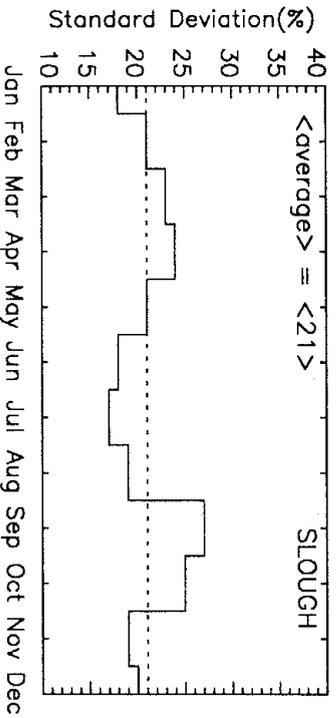
Patterns of F2-layer variability

H. Rishbeth^{a,b,*}, M. Mendillo^a

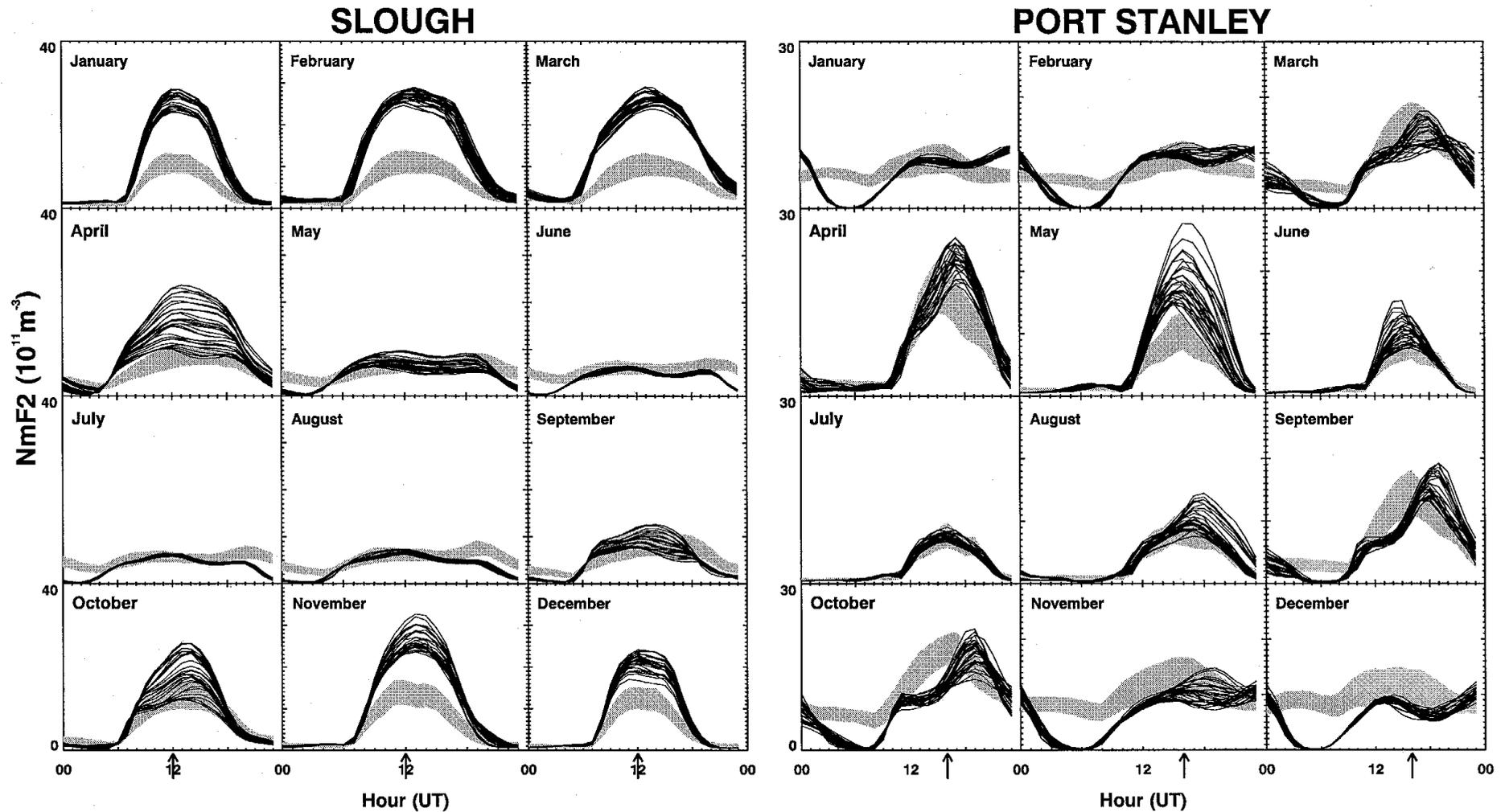


$\sigma_{SUN} < \sigma_{MAG} \approx \sigma_{MET}$

Fig. 2. Variation of NmF_2 at Slough for every day during four 2-month periods in 1973/1974.



NCAR/TIMEGCM-CCM3: Data - Model Comparisons

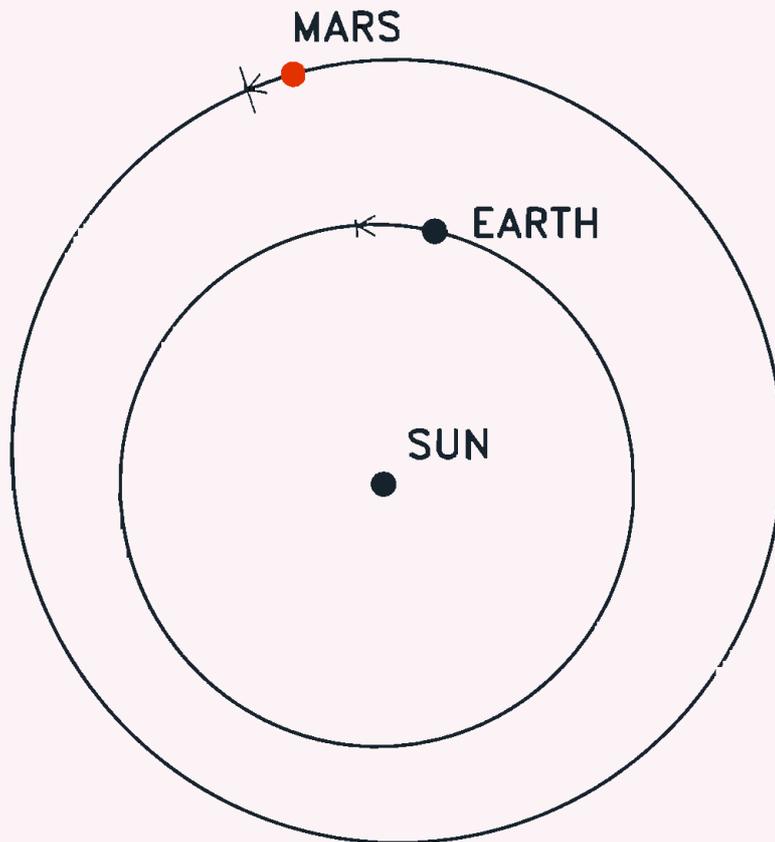


SHADING = Observed monthly mean NmF2 $\pm \sigma$

LINES = Model Values with solar and geomagnetic input held constant for a year of F10.7=140

MGS at Mars: Solar System Geometry

9–27 March 1999



Observing Conditions:

Lat.=69.7°N–73.3°N

Lon.=26.5°–273.0°N

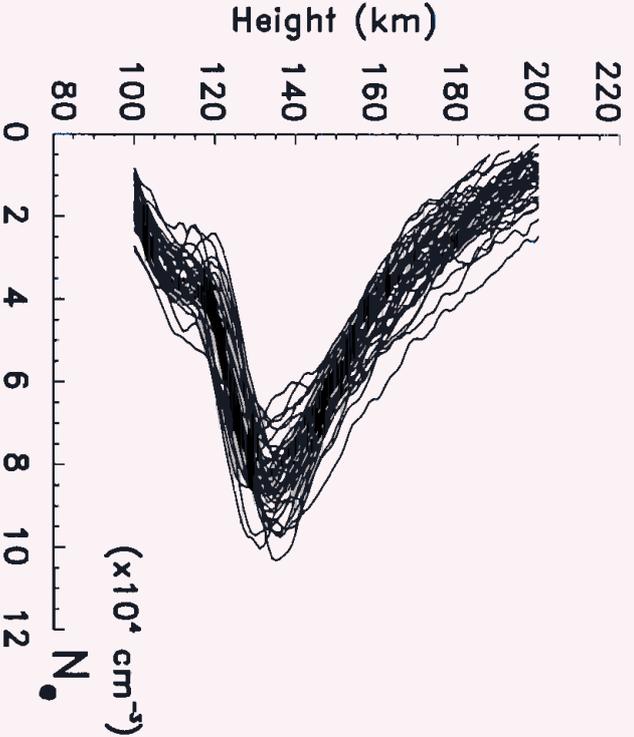
LT=3.6–4.1 hr

$\chi=76.5^{\circ}-77.8^{\circ}$

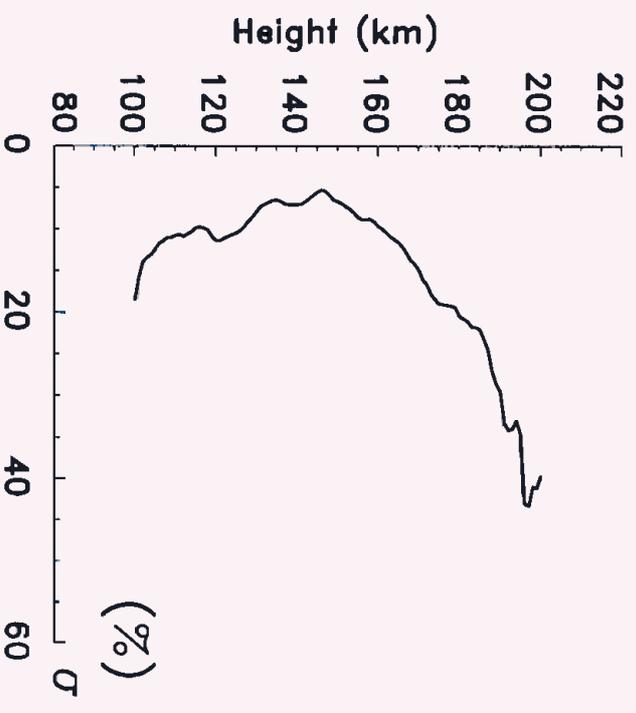
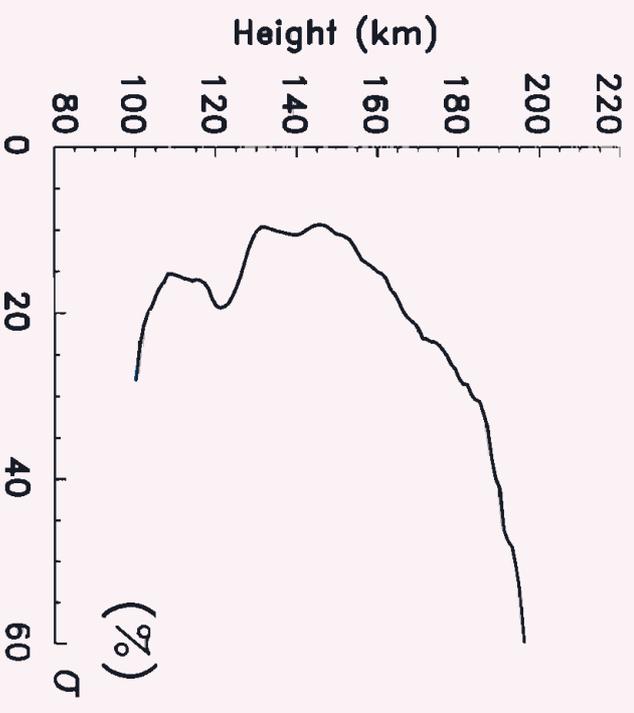
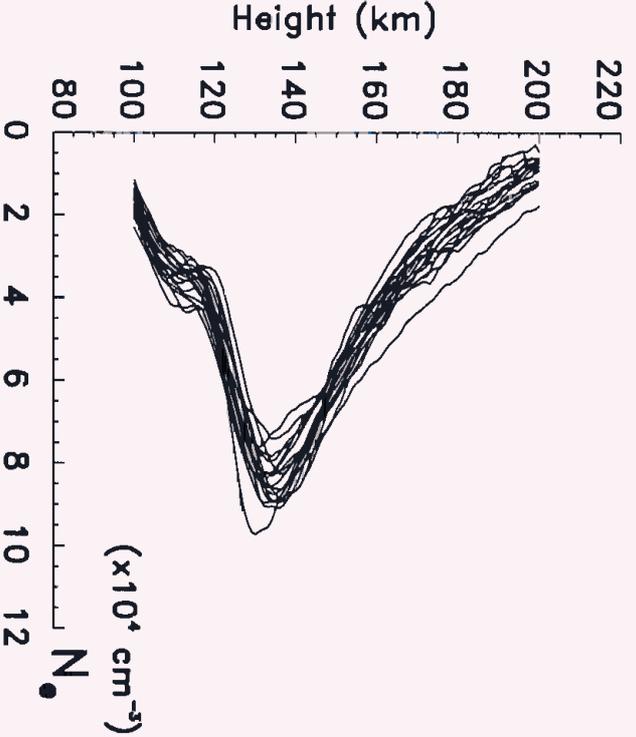
$F_{10.7}=103.1-154.7 \text{ Wm}^{-2}\text{Hz}^{-1}$

MGS at Mars: Radio Science Experiment Electron Density Profiles, $N_e(h)$

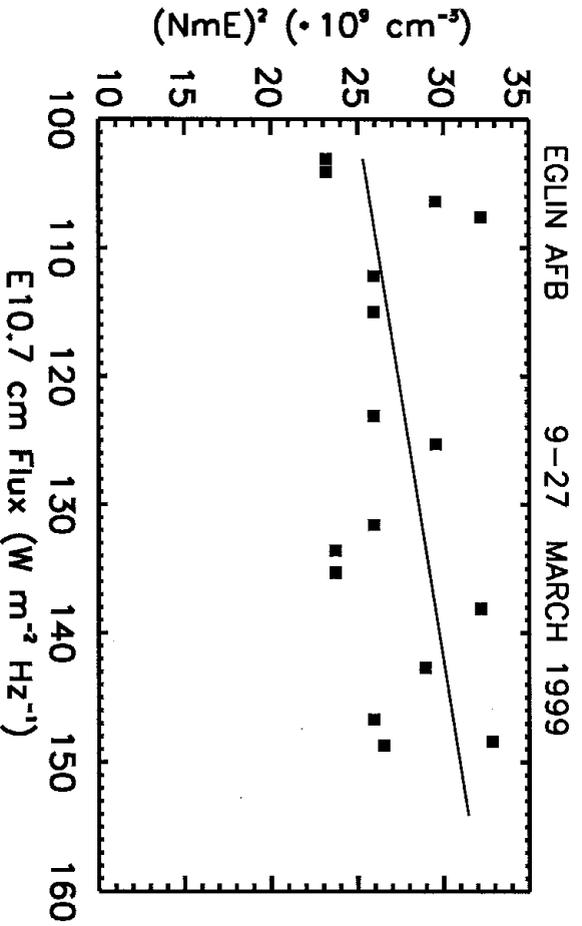
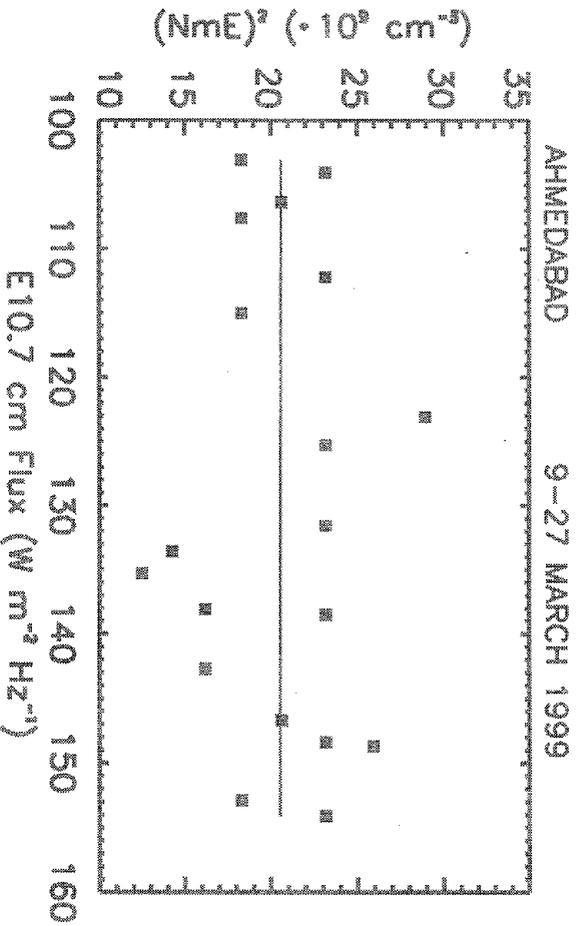
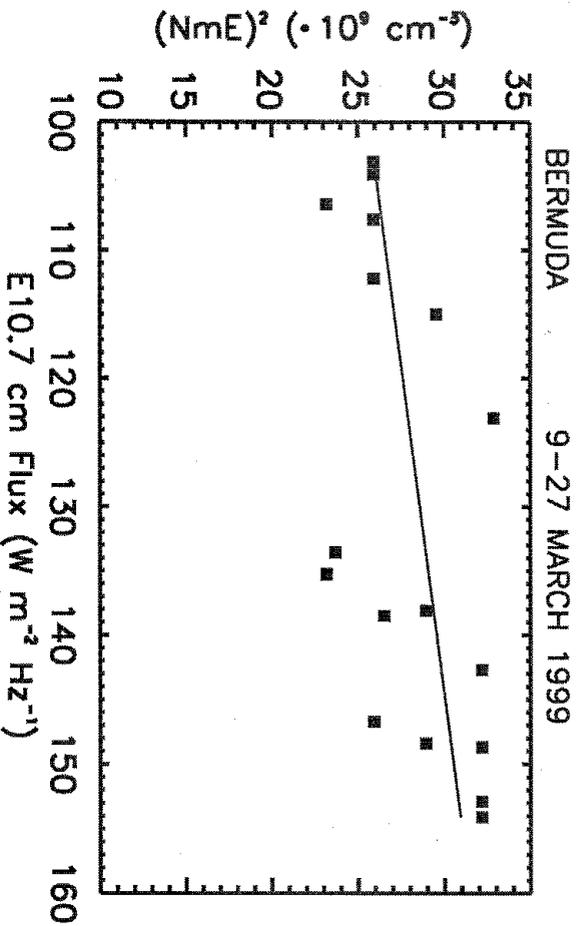
9–27 March 1999: 43 Individual Profiles



9–27 March 1999: 18 Daily Mean Profiles



Noon $N_m E$ at Earth Sites During MGS Periods at Mars



CONCLUSION

IUGG REPORT: (Nagy et al., 1995):

“The very basic processes such as ionization, chemical transformations and diffusive as well as convective transport are analogous in all ionospheres;

The major differences are the result of factors such as different neutral atmospheres, intrinsic magnetic field strength, distance from Sun, etc.

Improving our understanding of any of the ionospheres in our solar system helps in elucidating the controlling physical and chemical processes in all of them.”